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WATER SANITATION AT KRUG PARK SWIMMING POOL, OMAHA, NEBRASKA¹

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For some time sanitarians and public health officials have had their eyes turned toward the public and private swimming pools. That these pools are a menace to the public health, if not conducted along sanitary lines, is the opinion of all who have made an investigation of the subject. Unfortunately, when such bacteria as produce disease in man are encountered, they are generally found more or less closely associated with mankind. Anything that comes more or less in general contact with a number of different individuals, as does the water in a swimming pool, may be looked upon with suspicion, for it is sure to contain organisms associated with mankind.

Science has established the fact, that the body of a man of clean habits, having but a small amount of hair, may harbor several billion bacteria. A hairy man of clean habits was found to harbor fourteen billion bacteria, while on the body of an unclean man, having an average amount of hair, was found twenty-five billion bacteria. These figures may seem large to those who are not familiar with bacteriological technic, yet those, who are familiar with microscopic work, know the number of organisms that will adhere to a standard platinum loop from a broth culture, will readily see that these figures are not excessive. In making your mental picture of the horde of microorganisms from the average human body, remember, that if it were possible to so concentrate them, they could all be contained within a few drops of water and still there would be room for more, for a single drop of water may harbor as many as five hundred million organisms.

Science having established, within a reasonable degree of accuracy, the number of bacteria that might be found on the average human being, let us now engage in solving a problem in simple arithmetic. Let us take a pool having a capacity of one million gallons of water, with an average weekly attendance of ten thousand

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bathers. Assuming that the average bather's body contains fourteen billion organisms, of which seven billion find their way into the pool water, expressing the results in the number of bacteria per cubic centimeter, it will be found that this pollution alone, allowing nothing for the growth in seven days, nothing for the original germ content of the water, will amount to twenty thousand bacteria per cubic centimeter. It is true that in some clubs and private pools each bather is required to take a soap and water bath before entering the pool. In others they are required to take a shower, yet a soap and water bath, or shower, will not eliminate the possibility of human contamination.

Regardless of any set of rules laid down as to the conditions under which an individual may enter a swimming pool, there is another source of human contamination that must be taken into consideration. People will expectorate into the water and by so doing will contaminate the pool, not alone with the normal flora of bacteria found in the mouth, nose, throat and upper air passages, but with other more pathogenic bacteria such as the tubercular, diphtheria and influenza bacillus.

Germes always associated with venereal diseases may find their way into the water, as well as streptococcus, staphylococcus, and pyocyanus, all of which have been found in the urinary tract. It will be seen from this that if one is to make a study of swimming pool sanitation all possible sources of contamination must be considered and each individually or collectively dealt with, if one is to render a swimming pool safe and free from danger of infection. In addition to this, if a pool is to be a success from a financial standpoint, the surroundings must be attractive, the water clean, fresh, and inviting, for the better class of people will not pay to bathe where the water is stagnant, and filled with the growth of water algae.

In the June, 1920, issue of *The American Journal of Public Health*, appeared an article by Gordon M. Fair, in which Fair brings out three paramount facts that are of importance in determining the inferential index of swimming pool purity. These he defines as bathing load, index of stagnation, and index of contamination.

Bathing load is defined as the number of bathers per week, divided by the capacity of the pool in thousands of gallons. Thus, a pool having a capacity of fifty thousand gallons, with a weekly attendance of twelve hundred bathers, would have a bathing load of twenty-

four. It will be seen from this that there is a relation between the capacity of a pool and the number of bathers that safely use it in a given length of time.

Webster's dictionary defines the word stagnation as the state of being stagnant, while stagnant is defined as being motionless, to become impure or foul by want of motion or to become dull or inactive. The term index of stagnation is thus correctly applied. When this index is calculated, by taking into consideration the number of gallons of fresh water added to a pool each week, together with the number of gallons of water filtered and circulated each week, the whole in thousands of gallons divided into the number of bathers per week, an index of stagnation is correctly established.

An index of contamination may be calculated that will give an inferential index of the condition of the water in any pool by adding together the number of gallons of fresh water added to the pool each week, the number of gallons of water sterilized each week, the whole in thousands of gallons being divided into the number of bathers per week.

It will be seen from the foregoing that there is in all cases a relation between the number of bathers in a given time, the size of a pool and the amount of filtered and sterilized water. This all reverts back to what was said in the beginning that there is a fixed possibility of contamination from each bather who enters a pool and that the larger the volume of water per bather, the less the bathing load; the larger the volume of fresh and filtered water per bather, the less the index of stagnation and last, but not least, the larger the volume of sterilized water per bather the less are the possibilities of infection.

In the sterilization of swimming pool water many methods are resorted to. Ozone is being used, the violet ray is being used as well as liquid chlorine, chlorinated lime and several other agents. It has been my experience that it is impossible to maintain the water in a swimming pool for any length of time in a safe condition unless some method of sterilization is used that actually imparts germicidal properties to the water. There is no question but what ozone, when brought in contact with bacteria in sufficient quantity, will kill all pathogenic organisms. The violet ray will also kill bacteria when effectively applied even to the spores of many organisms, yet neither of these methods of sterilization imparts any germicidal properties to the water. The way that the ozone and the violet ray apparatus

must be installed is such that only such water as is actually circulated reaches the apparatus for sterilization. Regardless of how well the distributing system is arranged, there is always water in the pool that does not reach the sterilizing apparatus, to say nothing about the silt that always remains for the most part in the bottom of the pool and is a fertile field in which bacteria may grow.

The problem of water sterilization for swimming pools is very much different from that of a domestic supply. In sterilizing water for domestic use the pipe lines can be so arranged that every drop of water pumped into the supply mains must pass through the sterilizing apparatus, after which it is not subject to any further contamination until it is consumed. In the case of a swimming pool it is impossible to so arrange the distributing system that you are assured that when you have circulated the capacity of the pool that all the water in the pool has actually been through the sterilizing apparatus. In addition to this, the water in a swimming pool is continually receiving new contamination. If the water does not possess germicidal properties, this contamination must await its time to go through the sterilizing apparatus before being destroyed, and during this time it cannot be other than a source of danger of infection, if of an infectious nature. To bring out more clearly just what this actually means let us examine how the weekly bathing load in an outside pool is distributed. Let us assume a total capacity of one million gallons of water with a weekly attendance of ten thousand bathers. This load would be divided about as follows: Monday, Tuesday, Wednesday, Thursday and Friday one thousand per day or five thousand bathers for the five days. Saturday being pay day, a half holiday, the load for the day would be double that of any other week day or two thousand bathers. Sunday being a day of rest and recreation the load would be increased to three thousand for the day of which two thousand to twenty-five hundred would come between the hours of three p.m. to ten p.m.

In calculating the weekly bathing load on this basis it is found to be ten, which is well within the limit. The bathing load for any day from Monday to Friday is but seven which is still lower than the weekly average load. Saturday with two thousand bathers would raise the load to fourteen, while Sunday with three thousand bathers would increase the bathing load to twenty-one. If the bathing load on Sunday is calculated between the hours of three and ten p.m., taking two thousand five hundred as the number of bathers,

the load is raised to the high point of thirty-five. This exceeds the maximum allowable load of twenty by fifteen points. Again we may go back to what has been said before that the possibilities for contamination are directly proportional to the number of bathers in a given length of time. Where this number is high, and the water does not possess sufficient germicidal properties to take care of this flood of contamination, there is no question but that the danger of infection is increased. Repeated bacteriological examinations of water in swimming pools each day of the week where several different methods of sterilization were used substantiate the statement that has been made.

Krug Park swimming pool is located in the amusement park of the Krug Park Amusement Company, situated in the north west part of the City of Omaha. The pool is owned and operated by the Park Bathing Company. The ground is high. In fact there is a point within a few hundred feet of the pool that is the highest point in Douglas County.

The ground plan of the pool is triangular in shape, the base of which is 250 feet, the altitude 180 feet. The hypotenuse, instead of being a straight line, is curved outward to such an extent that it gives the pool a surface area of nearly twenty-five thousand square feet. The contour of the bottom is such that the water ranges in depth from 18 inches to 10 feet. The deep water is located next to the wall on the two hundred and fifty foot side of the pool, where are also the bath house and wave machines. The deep water covers a comparatively small area of the pool, 80 per cent of the area being water from 18 inches to 6 feet deep.

The pool is built entirely of concrete with the seams joined with a U-shaped copper expansion joint. The top $\frac{1}{2}$ -inch seam is filled with asphalt and tar. The wall surrounding the pool is so cast that a scum gutter is formed in the wall. This scum gutter has outlets every 10 feet to a drain line around the pool that leads to the screen chamber or to the sewer. This permits the movement of the water to carry into the scum gutter any floating matter. Two wave machines located on the bath house side keep the water in constant motion.

Nearly surrounding the pool is a sand beach 25 feet wide, the bottom and outer wall of which is concrete. Into this space nearly one hundred cars of washed sand were unloaded that the bathers might enjoy the sand bath.

In the northwest corner of the pool is located a water falls or cascade. This cascade is equipped with an 8-inch centrifugal pump that has a capacity of 2000 gallons of water per minute. Water is taken from the pool, passed over this cascade, where it is exposed to the light in thin layers, being freshened by liberating the dissolved gases.

The water plant of the Park Bathing Company is equipped with a direct connected motor and centrifugal pump, having a capacity of 1400 gallons of water per minute, that is used as a circulating pump. Three horizontal pressure filters, each having a capacity of 400,000 gallons of water in eight hours, are used for filtering the circulated water. In addition to the above, there are installed three 30 foot ozone towers, three ozone generators, a motor driven air compressor and switch board. Three adjustable transformers for stepping up the line voltage from 220 to 20,000 volts are a part of the equipment.

The circulated water is taken from what has been termed the screen chamber. This chamber is a concrete well, 6 or 8 feet square, that is divided in the center by a frame work covered with an eighth inch wire screen. A 15-inch pipe brings the water from the center of the 10-foot depth area into the screen chamber. An 8-inch pipe line brings the water from the scum gutter into this chamber. The valve arrangement is such that the screen chamber may be drained and cleaned at any time. This is essential as the scum gutter line carries into this chamber many particles of floating matter while sand and silt are carried in by the 15-inch line from the deep water.

The circulating pump takes the water from the screen chamber and passes it through the filters. After being filtered the water goes to the number one ozone tower. The ozone towers are mounted on steps so arranged that the water goes into number one tower at the top and passes out at the bottom. A vertical pipe carries the water from the bottom of number one tower to the top of number two tower and so on until the water passes through all three towers. From the bottom of the number three tower the water is carried up through a vertical pipe to near the height of the water in the number three tower, from which point it is piped to the line that carries it back to the pool. The top of this line is provided with an extended pipe to the atmosphere to prevent siphoning. This arrangement makes it necessary for all circulated water to pass through the three ozone towers where it is treated with ozone.

The ozone is generated in three horizontal tanks in which are located the ozone generating cells. The cells generate the ozone at from fourteen to twenty thousand volts. Compressed air, at 15 pounds per square inch, carries the ozone from the tanks where it is generated into the water. The air lines enter the ozone towers at the bottom, passing up through the water which is flowing downward. This insures a thorough mixing of the ozone, air and water.

The ozone generating cells are very sensitive to moisture, hence all air used must be dried. Between the air compressor and the ozone generating tanks a small trap and air storage tank is installed. This tank catches any lubricating oil from the compressor, acts as a governor between the generating tanks and air compressor as the tank is equipped with a valve, set to maintain fifteen pounds of air pressure. The air intake of the compressor is piped to a large air drying chamber. This chamber is so arranged that all air entering it must pass back and forth over several tray shelves filled with calcium chloride.

The capacity of the pool as calculated from the drawings is something over eight hundred thousand gallons. The capacity of the filters, ozone towers and pipe lines brings the total capacity of the system up to nearly one millions gallons of water. The capacity of the circulating pump being fourteen hundred gallons per minute, eighty four thousand gallons per hour, this means that a million gallons of water may be passed through the system every 12 hours.

The water that is returned to the pool is carried in a loop shape pipe line that completely surrounds the pool. There are twenty-four small outlets from this loop line into the pool. These outlets discharge into the pool at an opening at the very bottom of the outside wall. This creates a flow from the shallow water at the outside wall to the center of the 10-foot depth area where the outgoing line is located.

When the water has been filtered and ozonated it is chlorinated just before it enters the pool. The diffuser tube that carries the chlorine into the water is located in the main pipe line about fifteen feet above the point where the line divides to form the loop above referred to. The chlorinating apparatus was not installed until the first of May, 1921, so it will be seen experience has been had with ozone only the first year, ozone and chemicals the second year, chlorine with or without ozone this year.

When the chlorine apparatus was started this year it was set to feed at the rate of six pounds in twenty-four hours. The flow of water passing the diffuser tube was 84,000 gallons per hour. Six pounds was at the rate of 0.175 p.p.m. The water in the pool was turned over twice in twenty-four hours so it will be seen that at this rate 0.35 p.p.m. of chlorine was actually being fed to the pool water each 24 hours. This did not prove satisfactory. The total number of bacteria kept slowly increasing, as did the *B. coli* index, all in face of the fact that the water was filtered twice in twenty-four hours. The dosage was next increased to twelve pounds in twenty-four hours or double the amount first started with or 0.7 p. p.m. in twenty-four. This gave slightly lower counts on twenty four-hours' incubation, but still not satisfactory. The plates on being incubated 96 hours showed two to three times the number of organisms seen at 48 hours.

The next step was at the rate of 18 pounds in 24 hours or 1.05 p.p.m. This made a great improvement over 12 pounds, but still the total count in 48 hours was not satisfactory. Feeding at this rate the *B. coli* index was near five to six in 100 cc., while the number of 37° organisms was 5000 per cubic centimeter. If a sample was taken after a large number of bathers had been in the pool, the colon index as well as the total count would be materially increased.

It was decided to again increase the charge. This time it was raised to 25 pounds in 24 hours or at the rate of 1.5 p.p.m. Instructions were left with the operator to watch very closely for odor of chlorine. If they developed, he was to close down the chlorine apparatus. Feeding at this rate no odor developed until the end of the third day, when the operator detected a strong chlorine odor at the cascade. This odor was not noticed by the bathers and no one complained of the water affecting the eyes. A sample of the water was taken from the center of the pool within 12 inches of the bottom for bacteriological examination. It showed a total count of 450 37°C. organisms per cubic centimeter on 48 hours' incubation, which was increased to 640 on 96 hours' incubation. Not a single colon reaction was found in 100 cc. examined, using a lactose peptone bile media containing 5 per cent of ox bile instead of 10 per cent as standard.

It was not believed at first that it would take this amount of chlorine to effect sterilization. A record was kept of two weighed tanks of chlorine with the result that the chlorine apparatus was

actually feeding the amount of chlorine indicated by the apparatus. An analysis of the water, feeding at 25 pounds, showed that it contained nearly 0.5 p.p.m. of free chlorine. The water was so clear you could see a dime on the bottom at the 10-foot depth. The oxygen demand, or the amount of oxygen consumed from an acidulated solution of potassium permanganate, was between 24 and 25 p.p.m. The puzzle was where the extra one part per million was going.

We had two or three cloudy days and the feeding at the rate of 25 pounds on these days soon developed a strong odor of chlorine from the water. The bathers could not detect this odor, but the operator could, and the starch iodine test would verify it. The reaction was very pronounced. It was finally decided that it was the light that was consuming a part of the chlorine, so the order was given to feed at the rate of 25 pounds at night and to cut down to 8 or 10 pounds during the day. This gave just as good results and saved many pounds of chlorine during the season. The pool was opened on May 29 and closed September 5. This was a season of 95 days in which time the pool was not emptied. In this length of time nearly 900 pounds of liquid chlorine were actually used.

When it was finally determined just what was required in the way of chlorine dosage, it was found that there was very little change in the water from day to day. Samples for bacteriological examinations were always taken about nine o'clock in the evening, thereby representing the maximum pollution of the day. Regardless of the number of bathers there was little variation in the total number of organisms present or the *B. coli* index. The average was nearly 450 per cubic centimeters with no lactose fermenting organisms in 100 cc. The colonies of bacteria that did develop in 48 hours were all small ones. No fully virulent organisms were encountered in plating 1 cc. of the water, except that occasionally a colony of *B. subtilis* would overgrow a plate. Plates set with 1 cc. of the water on such culture media as methylene blue eosin agar, Endo's and Krumwiede's brilliant green agar would develop no colonies except an occasional mold on 48 hours' incubation.

During the latter part of the season an examination was made of the sand and silt in the bottom of the pool. It was found that the total number of 20°C. and 37°C. organisms per gram were much greater than in the water. Fifty grams of the sand and silt were shaken up and washed with sterile water and the wash water set in

fermentation tubes in amounts to represent 1-2-5 and two 10 cc. tubes. All five tubes reacted with a stormy fermentation, but confirmation tests failed to show that *B. coli* was the reacting organism. As an ox bile culture media was used in the first place and all reacting tubes were methyl red negative, it was assumed that the reactions were due to the spores of *B. welchii*. Washings, representing 1 gram of the silt, were set on such selective culture media as M.B.E. agar, Krumwiede's brilliant green agar, and a special lead acetate media containing brilliant green in an amount equal to one part of the solid dye to five hundred thousand parts of media. While it was impossible to count the number of colonies that developed in 48 hours on these plates there was not a colony of a lactose fermenting organism on any of the plates, nor a lead acetate reducing organism on the lead acetate plate. All media contained an indicator so this differentiation was possible. All standard agar plates set below one to one thousand overgrew in 48 hours with the *Bacillus subtilis*.

A disinfectant is usually described as a substance capable of destroying bacteria, while an antiseptic is one that restrains or retards their growth or reproduction. This distinction is entirely arbitrary, for the enumeration of bacteria by means of solid culture media, depends upon the ability of the organism to reproduce at such a rate as to form a visible colony within a specified length of time. Chlorine, hypochlorites and ozone, even in minute doses, exert a toxic effect that is sufficient to kill some organisms, but if in still smaller concentrations are employed, the toxic effect is transient and the reproductive faculty may be entirely regained. In actual practice no substance acts entirely as an antiseptic as the organisms present have varying degrees of resistance. What will kill one organism may but put another in a state of suspended animation, with the faculty of recuperation, and yet leave another more resistant organism untouched.

An example of the antiseptic action of chlorine may be had by reviewing the experience gained in determining the chlorine dosage at Krug Park Swimming Pool. Here the mild antiseptic action of chlorine at a dosage of 0.35 p.p.m. in 24 hours is plainly set forth. Plates were read at the end of 48 and 96 hours with the results that in 96 hours the total number of visible colonies were two to three times those seen in 24 hours. As the dosage was increased not only did the number of organisms decrease but the size of the colonies of the organisms growing were decreased.

There is no evidence of the fact that there is any marked difference in the resistance of ordinary water bacteria to chlorine and that these are the first to be affected by the added germicide. On the other hand there is considerable evidence to the effect that *B. coli*, and other members of the intestinal flora, are slightly more susceptible to destruction by chlorine. It was found at Krug Park that it was necessary to eliminate all non-spore bearing lactose fermenting organisms in 100 cc. of water in order to bring the total count of 37° organisms below 500 on 48 hours' incubation. At a chlorine dosage sufficient to do this the colonies on the plates incubated 48 hours at 37° would all be very small, showing either that those surviving were attenuated, or that they were of a type not suited for growth on standard agar culture media. Tests made on broth cultures showed that a large part of them were not spore bearing organisms. Counts were made at 20° and at 37° in many cases, with the results that the number of 37° organisms were always greater than the 20° organisms. The ratio was found to be near 80 to 100.

The standard of purity that has been taken in the case of the Krug Park Swimming Pool is that of the Treasury Department of the United States Government. The State of California limits the number of 37° organisms to 1000 per cubic centimeter with not more than one *B. coli* per cubic centimeter. This allows for a colon index of 100 which is by far too many, as the writer personally views it, on account of the known human contamination. My experience with chlorine is that a dosage sufficient to keep the total count in an outside pool below 1000 per cubic centimeter is sufficient to maintain a colon index of not more than 10 to 15 per 100 cc. Last year some experience was had with chloramines at a number of pools in the State that brought out some surprising results. At a dosage of one-fifth to one-eighth that of liquid chlorine used at Krug Park, calculating the chloramines on a chlorine basis, total counts as low as four to six organisms per cubic centimeter were obtained with no non-spore bearing lactose fermenting organisms in 100 cc. Sufficient information is not at hand at this time to draw definite conclusions. Only extended work over a period covering an entire bathing season without draining the pool will bring out further information. This work is to be continued next year, as well as some work on the flora of bacteria that survives treatment with chlorine and chloramines.